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SRC Technical Report No. 164

Publication E-910-6-B-84

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INTRODUCTION

The wheat midge (Orange Blossom Wheat Midge or Sitodiplosis mosemana) caused extensive crop damage in northern Saskatchewan in 1983. A large area of cereal crop fields in northeastern Saskatchewan was again infested in 1984. The range of host crop for the midge is not known; however, wheat is likely the preferred host.

The only part of the plant damaged by the wheat midge is the developing seed. When a kernel of grain is attacked during the early stages of development by a single larva, or in the later stages by several larvae, it will either not develop at all or develop as a shrivelled, deformed kernel.

The life cycle of the wheat midge is: adult stage, egg laying and hatching stage, larva stage, cocoon (dormant) stage, and pupation stage. Adult midge flies emerge from the pupae stage in late June or early July. The females mate almost immediately after they emerge. During the day, the adult midge stay within the crop canopy where conditions are humid. In the evening or during periods when skies are overcast, the females seek out susceptible plants on which to lay their eggs. Cereal crops are prone to attack as the heads begin to emerge from the boot. An average of 40 eggs may be deposited during the lifespan of the female midge, which usually lasts less than 72 hours. The egg stage usually lasts four to seven days. Upon hatching, the small orange larvae find their way to a developing kernel of grain where they feed on the surface of the seed. Larvae feed and develop for about two to three weeks, by which time they are about two to three millimetres in length. The larvae can survive in this state without shedding their

skin for up to two months. As soon as conditions become moist or wet, they become active and crawl off the wheat heads to bury themselves in the soil.

Most of the larvae remain in the top layer of soil (5 cm) where they form round cocoons and become dormant. In this stage, the larvae may remain in the soil for up to 13 years or more. The larval diapause may be broken if the larvae are cooled below 10°C for 120 days and then maintained under moist conditions at 22°C for 24 or more days. Larvae then become active and move to the soil surface to pupate. Adults begin to emerge from the pupal stage in late June or early July. This may continue for about six weeks.

Once fields are heavily infested with wheat midge, protecting spring wheat from this insect is difficult. One or more stages in the life cycle may be controlled with an insecticide, however, chemical control should only be used when the cost of control is less than the value of the crop destroyed.

With the cooperation of Mr. O. Mysak, Agricultural Representative for the Canora district and local farmers near Norquay, a one-day spray drift sampling was conducted in a wheat field 7 km southeast of Norquay on July 24. The insecticide used is "Furadan" (PCPA Registration No. 10828). A local applicator with an Ag-cat biplane cooperated in the test.

The spray liquid was mixed with a fluorescent dye and the deposition samples were analyzed flurometrically. This report presents the results of spray drift and penetration of spray chemical through the crop canopy and into grain kernels.

I. PROBLEMS IN WHEAT MIDGE INFESTATION CONTROL

1. Pesticide Spray Formulation

Furadan®, which belongs to the carbamic insecticide family, contains 480 g of carbofuran (active ingredient) per litre of liquid concentrate and is applied at a rate of 275 mL/ha. The concentrate was mixed with water at a rate of one container (4 L) per 1575 L of water and applied at a rate of 55 L/ha (or 5.0 GPA).

An Ag-Cat (biplane) was equipped with 37 spray nozzles alternately D8 (45) and D12 (45), oriented straight down, and employed hydraulic pressure of 300 KPa (or 43 PSI). The aircraft cruised at 175 km/hr (110 MPH) over a field, maintaining a cruising height of 1.5 m (3 ft.) above the crop, perpendicular to the prevailing wind direction.

The preferred size spectrum of spray droplets for such a nozzle arrangement may be adequate for herbicide spraying intended for broad leaf weeds. The optimum droplet size spectrum for aerial applications for control of wheat midge is not clearly identified. The target geometry in the process of droplet deposition was wheat heads rather than individual insects at the growth stage of wheat midge. The translocation mechanism of deposited insecticide to the insect body seemed complicated, however, it is out of the scope of this investigation.

2. Growth Stage and Time of Effective Control

The strategies of infestation control may be aimed at any of the following growth stages: control of adult flies, control of eggs, control of larvae in cropheads, and control of pupa in field soil. For aerial application of systemic insecticide, chemical control at the larva and adult stages seems most effective, though the survival period of adult

flies is very short and dependent on ambient temperature and moisture. Therefore, a chemical control of adult flies before laying eggs seems extremely difficult due to the time limitation.

The stage of growth for this investigation was the larvae stage and orange-colored insects were visible inside the wheat head, under a magnifying glass.

3. Penetration of Pesticide Spray

When larvae are in transient stage to pupation, they migrate toward the soil surface. If pesticide spraying is done at this stage, the spray cloud must penetrate sufficiently through the crop canopy to the lower part of the plants. The mechanisms of crop canopy penetration are complicated, however, an approximate estimation of penetration may be made by locating sampling targets at the height of the crop head and at the soil surface in a spray swath.

The adult flies may lay eggs between the florets inside the wheat head after the wheat head emerges from the boot. The newly hatched larvae remain within the wheat head and present a difficult target to reach with insecticides. The spray droplets, aerially applied, must possess sufficient energy to penetrate the wheat heads that comprise complicated geometry. For this study, the wheat head penetration seems more realistic in evaluating control efficiency of aerial application.

4. Efficacy Assessment

The efficacy of insecticides in infestation control greatly depends on the stage of growth at which the chemical was applied. Since the size of insect is so small, it is a difficult and time consuming task to determine the control effect by population count. An insect net or

sticky tape and a magnifying glass were used as a standard method by a local investigator.

The best way to evaluate the control effect of an infested area may be to inspect the heads at harvest time. Unfilled or partially filled kernels present in a head can be attributed to midge damage.

II. SAMPLING AND ANALYTICAL METHOD

1. Sampling Layout

A border section of a farmer's infested wheat field was chosen for the sampling of the pesticide during the aerial spraying operation.

Clean petri dishes of 15 cm diameter (0.015 m^2 collecting area) and jumpcards (water sensitive indicator coated, 15 x 20 cm) were placed both within the swath and downwind of it. An array of 15 dishes was placed on the ground within areas cleared of the wheat plants. Eleven jumpcards, mounted on thin metallic clipboards, were placed on the ground alongside some of the petri dishes. Another set of jumpcards were exposed at the height of the wheat heads alongside some of the petri dishes. Thus the droplet size distribution and density with respect to the height of the wheat plants and the ground level could be determined. The off-swath petri dishes and jumpcards were placed on the ground within 30 metres of the swath (Figure 1).

2. Sample Collection

After one pass of the aircraft over the swath, the jumpcards and dishes were removed. The dishes were covered and stored in dark plastic bags and placed in styrofoam containers with ice. A fluorescent dye (brilliant sulfoflavin or BSF) was mixed to the spray solution at a

rate of 0.16%. The technique of fluorescent dye tracer in spray drift studies has been established (Yates, 1963). Meteorological observations were taken before and during the trial by using a hand-held anemometer and by referring to the nearest local office of an agricultural representative.

Several heads and stems of the wheat plants within the swath were sampled for laboratory analysis to determine the extent of penetration of the pesticide onto the wheat heads and stems.

3. Laboratory Analysis

Laboratory analysis of all the samples except the jumpcards consisted of the extraction of the active ingredient using varying quantities of high-grade ethanol. The resulting solutions were poured into small, labelled bottles and automated analysis of the samples was carried out using a flourometer.

The analysis and data reduction of the jumpcards followed the commonly applied procedures but a major part of the procedures were computerized to minimize human error. After fixing the stains, thirty-six representative areas were chosen on each of the jumpcards and all the stains on the jumpcards were size-counted to one of ten size classes. After applying a spread factor, the corresponding sizes generated corresponding solution volumes which were plotted as cumulative frequency curves. The 50% points intercept on these curves gave the volume median diameter for the sample. A newly developed software and IBM Computer Model 5150(PC) was used to obtain a printout of the results of the analysis and a graphical output of the cumulative frequency curves.

4. Fluorescence Analysis

The samples of complete wheat heads, wheat hulls and seeds, wheat stalks, and petri dish samples were extracted initially into 30 mL of ethanol. The samples were diluted by putting 200 mL into 18 mL of ethanol (91 x dilution). Blanks were made of petri dishes while four off-swath complete wheat heads served as blanks for the rest of the samples.

A Perkin-Elmer Model 204 Fluorescence Spectrophotometer with auto-sampler and printout was used to analyze samples. Standards of Brilliant Sulfo-Flavine (BSF) dye in ethanol were made for standardization of the instrument. Samples were extracted overnight, diluted and run the following day.

After extraction, the solutions containing plant fragments turned green due to chlorophyll "a" and "b" present in all green plants. The BSF dye added to the tank mix is yellow in a concentrated solution. There was some concern regarding the possible added flourescence of the chlorophyll "a" and "b" along with other flourescent natural products. The BSF dye solutions are excited at 420 nm and analyzed at 505 nm. In the absorption spectra of chlorophyll "a" and "b" (Geise, 1968) there is appreciable absorption at 420 nm but virtually none at 505 nm. One would only see the BSF emission at 505 nm. The blanks of the complete wheat heads would take any small chlorophyll "a" and "b" or other natural product flourescent emission at 505 nm.

A photolysis factor of 5% was applied to the results in light of previous investigations (Yates, 1963).

III. RESULT AND DISCUSSION

1. Spray Application

A flat field with a swath extending from east to west, parallel to a farm (grid) road, was selected near Norquay. At the time of spraying, the spring wheat was in the early flowering stage. The height of the crop canopy was 90 cm.

The aircraft used was an Ag-Cat biplane equipped with 37, alternating D8-D12 nozzles. The time of spray application was 12:30 p.m. The air temperature at the nearest observation site (Canora Agricultural Representative's office) at midday was 32°C and the relative humidity was 30%. The winds were from the south at 8 km/hr.

The aircraft was loaded with 10% of its nominal payload for this trial to cover up to two consecutive swaths perpendicular to the prevailing wind direction (Figure 1).

2. Distribution of Swath Deposition Density

The swath deposition density of Furadan determined by the petri dish method at the crop canopy level was 2.88 mg/m² as compared to a calculated application rate of the chemical of 2.64 mg/m² (5 GPA), showing that the aircraft was applying Furadan close to the pre-set application rate. The swath recovery may be assumed to be practically 100%. Among five petri dishes laid out at canopy level in the swath the coefficient of variation (CV) was 49% (Table 1).

The cross-sectional distribution of the chemical was not skewed to the downwind side. The density at swath center was 2.4-4.9 mg/m², while it was 1.8 mg/m² on the upwind side and 1.6 mg/m² on the downwind side. The values obtained for ground surface showed more uniform distribution

across the swath (2.5 - 3.3 - 3.8 mg/m²) with CV = 21% (Table 1).

Values of volume median diameter (VMD) determined on water sensitive jumpcards were rather coarse for insecticide spray. This finding is attributed to the orifice size of nozzles (D8 and D12). The nozzles were oriented straight down, therefore, there must have been some shearing effect, producing finer droplets than original droplets for normal (zero degree) orientation (Figures 2-6).

The values of VMD at the canopy height were 182 μm, 231 μm, and 219 μm and it seems obvious that only larger droplets (VMD - 355 μm) with sufficient deposition energy, penetrated the crop canopy and deposited on the soil surface. The evaporation effect of airborne droplets on the downwind side (5 m downwind of swath edge) was exhibited by reduced VMD (190 μm) (Figures 2-6, Table 2).

The values of geometric standard deviation determined from the particle size distribution curve ranged from 1.3 to 1.6 showing relatively homogeneous particle size distribution (Table 2).

The droplet size spectrum, which results in the highest control for the wheat midge, is still unknown. It depends on the location and geometry of the wheat crop where target insects stay active.

3. Characteristics of Downwind Drift

Values of off-swath recovery at 5, 10 and 30 m downwind were compared to the mean swath deposition density at canopy level. There was a remarkable reduction of Furadan depositing at downwind distances. At 5 m immediately downwind from the drifting chemical 75% of active ingredient was deposited, while the recovery was reduced further to 10.4% at 30 m downwind (Table 3, Figure 7). The off-target drift immediately

downwind (5 m) was at the 30% level (70% deposited). For low velocity winds of 8 km/hr (or 5 MPH), at 2 m height, the recovery at downwind distances may still be comparable to existing results (Maybank et al. 1975).

4. Crop Canopy Penetration

The values of deposition density of Furadan on petri dishes, located at crop canopy and at the ground surface, were compared to obtain the canopy penetration. The values obtained elsewhere for wheat sprayed with low volume insecticide were about 60% (Charnetsky, 1984). Only Sample No. 3702 was directly exposed to spray because there were no crop canopies near the petri dish. By ignoring this extremely high value, the value of penetration reached 47%. This finding is mainly due to the method of spray application. The aircraft covered swaths parallel to the direction of the rows. If the aircraft sprayed perpendicular to the direction of the rows, this value would have been considerably lower due to capture of spray droplets by standing crops. It may be assumed under such a circumstance that the canopy penetration of Furadan was close to 50% (Table 4).

5. Penetration into Grain Kernel

After the spray operation, in the sprayed swath in the vicinity of sampling stations, wheat heads were collected and stored in screw-capped glass test tubes and kept in a dark, cool, container. Before laboratory extraction of BSF dye, all grain and chaff of the heads were manually removed and separated from the stalks. The residual fluorescence in grains and stalks was analyzed separately. Then the total amount of Furadan detected in grains and stalks was obtained. The amount of Furadan in the stalk divided by the total amount x 100 yielded the kernel

penetration. Except for a group of samples No. 3724-30, the values of kernel penetration ranged from 39 to 47% (Table 5).

The rate of penetration determined in field trials must be supported by data from a series of precise laboratory tests. The use of a plastic wheat head (dummy) for this purpose would provide realistic information on the penetration mechanism of spray droplets of various size spectra into the wheat head. The method was established elsewhere (Maybank et al. 1976). In addition to the "dummy" method, the dye-tracer method may be made more versatile by employing a UV photographic method to display the deposition and penetration pattern of droplets. Due to the difference of surface properties of dummy versus actual wheat heads, it is expected that some spray droplets impinging on the plastic head may bounce off and not have the same spreading action as on real wheat heads in the field.

IV. CONCLUSIONS

1. A biplane, which voluntarily participated in the test, produced adequate swath deposition distribution and off-swath recovery.

2. The size spectrum of the spray droplets was too coarse, compared to the acceptable size for insecticides.

3. The spray droplets penetrated through the crop canopy and 48% of the insecticide was deposited on the soil surface.

4. The spray droplets penetrated into the crop, with 39-47% of the total deposited on wheat heads.

5. Further studies are required to accumulate field data and to delineate the penetration mechanism of droplets into wheat heads by using dummy plants both in the fields and laboratory.

ACKNOWLEDGEMENTS

This field investigation was conducted as an SRC research project with the cooperation of Mr. O. Mysak, Agricultural Representative for the Canora District, Mr. Jim Nelson, a Norquay farmer (and researcher) and Mr. E. Parchewsky, an aerial custom applicator from Preeceville, Saskatchewan. The result was reviewed and comments were provided by Dr. R. Ford of Agriculture Canada Research Station, Saskatoon. The samples were analyzed by James Ross of the SRC Environment Sector. Figures were prepared by J.C. Sardinha of Graphic Services, SRC. The authors appreciate the cooperation and assistance provided by each of them.

V. REFERENCES

Charnetsky, W.: private communication, 1984.

Geise, A.C.: Cell physiology, 3rd Ed. 436 P., 1968.

Maybank, J., Yoshida, K. and Shewchuk, S.R.: Comparison of swath deposit and drift characteristics of ground-rig and aircraft herbicide spray systems (Report of 1975 field trials). SRC Publication P76-1, 1976.

Maybank, J., Yoshida, K., Shewchuk, S.R. and Grover, R.: Spray drift and swath deposition pattern from agricultural pesticide application (Report of 1976 field trials). SRC Publication P77-1, 1977.

Yates, W.E. and N.B. Akesson: Fluorescent tracers for quantitative micro-residue analyses. Trans. Amer. Soc. Agr. Eng. Paper, 1962.

Table 1. Swath Deposition Density (Petri dish)

Location	Sample No.	Furadan (mg)	Deposition Density (mg/m²)	Swath
Top of canopy	3685	25.3	1.6	Downwind side
	3689	37.8	2.4	Swath center
	3691	28.2	1.8	Upwind side
	3694	77.9	4.9	Swath center
	3695	59.0	3.7	Swath centre
Ground	3701	40.5	2.5	Upwind side
	3702	91.7	5.7 ⊗	Bare ground
	3703	52.4	3.3	Swath center
	3704	60.1	3.8	Downwind side

Canopy: $\overline{CV}$ = 49% $\overline{X}$ - 2.88

Ground: $\overline{CV}$ = 21% $\overline{X}$ - 3.20 ⊗ (less 3702)

Swath Only: $\overline{CV}$ = 36% $\overline{X}$ = 3.10

Table 2. Droplet Particle Size

Swath Location	Sample No.	Vol. Med. Dia. (μm)	Geometric Std. Deviation
Swath center, canopy	3687	180	1.60
Swath west end, canopy	3692	230	1.40
Swath center, canopy	2688	220	1.60
Swath, ground	3684	360	1.30
Downwind, canopy (5 m)	3682	190	1.60

Table 3. Downwind Deposition Distribution (Canopy)

Downwind Distance	Sample No.	Furadan (µg)	Dep. Density (mg/m²)	Off-Swath Recovery (%)
Swath (mean)	--	--	2.88	100
5 m	3683	33.9	2.1	73
	3699	28.6	1.8	62
10 m	3698	31.0	1.9	66
	3680	6.4	0.4	14
30 m	3678	4.0	0.3	10

Table 4. Penetration of Spray Through Crop Canopy (Petri dish)

Location	Sample No.	Deposition (mg/m²)	Penetration (%)	Swath
Canopy	3685	1.6	--	Downwind side
	3689	2.4	--	Swath center
	3691	1.8	--	Upwind side
	3694	4.9	--	Swath center
	3695	3.7	--	Swath center
	Mean	2.88	53	--
Ground	3701	2.5	--	Upwind side
	3702	5.7 ⊗	--	No crop canopy
	3703	3.3	--	Swath center
	3704	3.8	--	Downwind side
	Mean	3.20	47	--
TOTAL			100	

⊗ Value for bare ground, the mean value is without Sample No. 3702.

Table 5. Spray Penetration to Wheat Head

Location	Sample No.	Foradan (µg)	Stalk (µg)	Penetration (%)
In swath (East)	3724	1.8	0.21	10
	3725	5.9	0.21	3
	3726	UD	--	--
	3727	UD	--	--
	3728	0.2	0.21	5
	3729	1.1	0.21	16
	3730	UD	--	--
	Mean	--	--	9
In swath (West)	3738	6.6	1.6	20
	3739	1.5	1.6	52
	3740	2.0	1.6	44
	3741	2.0	1.6	44
	3742	2.0	1.6	44
	3743	2.0	1.6	44
	3744	3.1	1.6	34
	3745	2.0	1.6	44
	Mean	--	--	47
In swath (South)	3731	0.2	0.89	82
	3732	UD	0.89	--
	3733	1.8	0.89	33
	3734	2.0	0.89	31
	3735	7.3	0.89	11
	3736	0.9	0.89	50
	3737	1.8	0.89	33
	Mean	--	--	40
Downwind	3712	1.5	1.8	44
	3713	2.0	1.8	35
	3714	2.0	1.8	37
	3715	2.9	1.8	29
	3716	1.1	1.8	52
	Mean	--	--	39

UD - undetectable

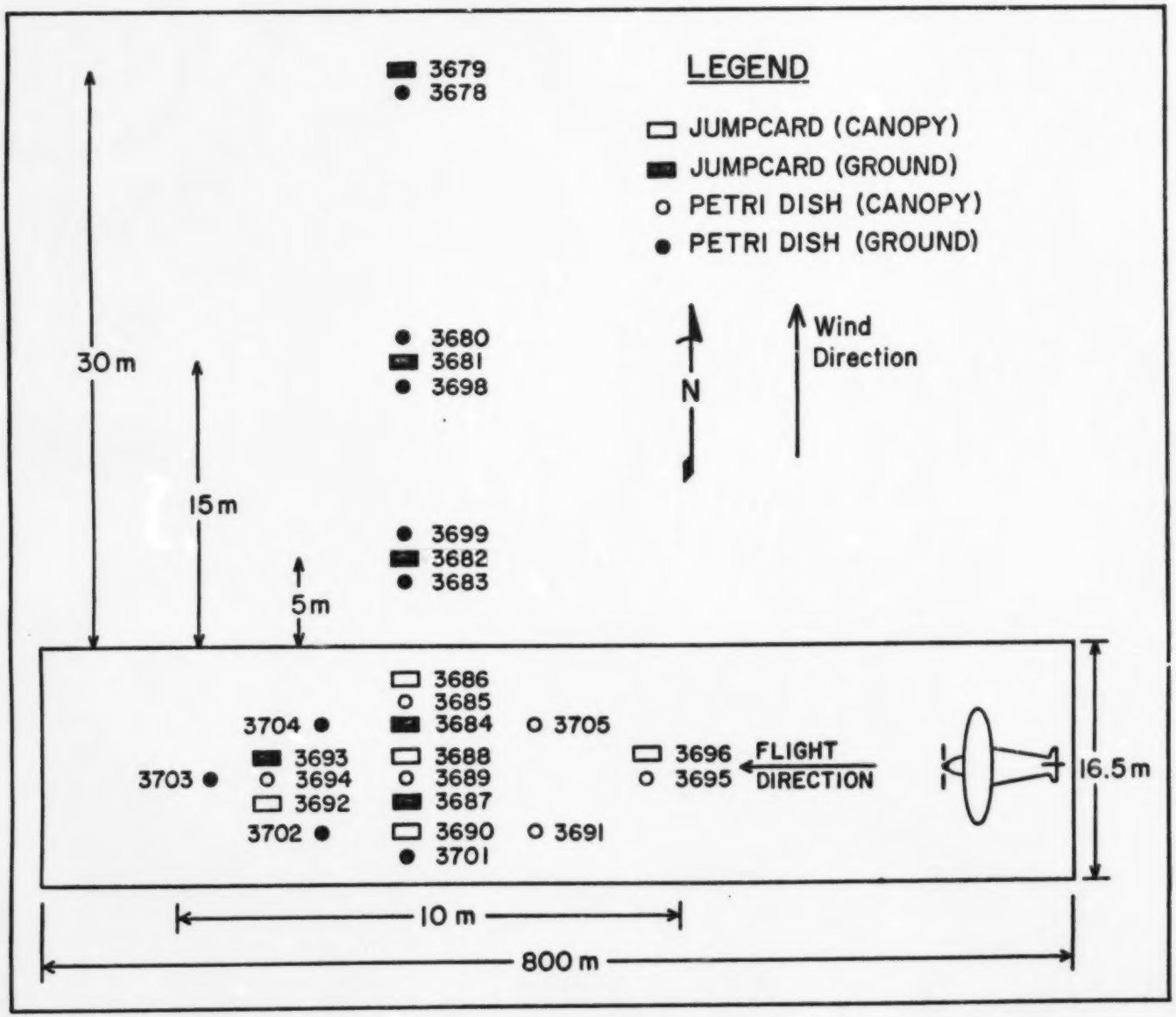

Figure 1. Field Layout of Midge Spray Trial

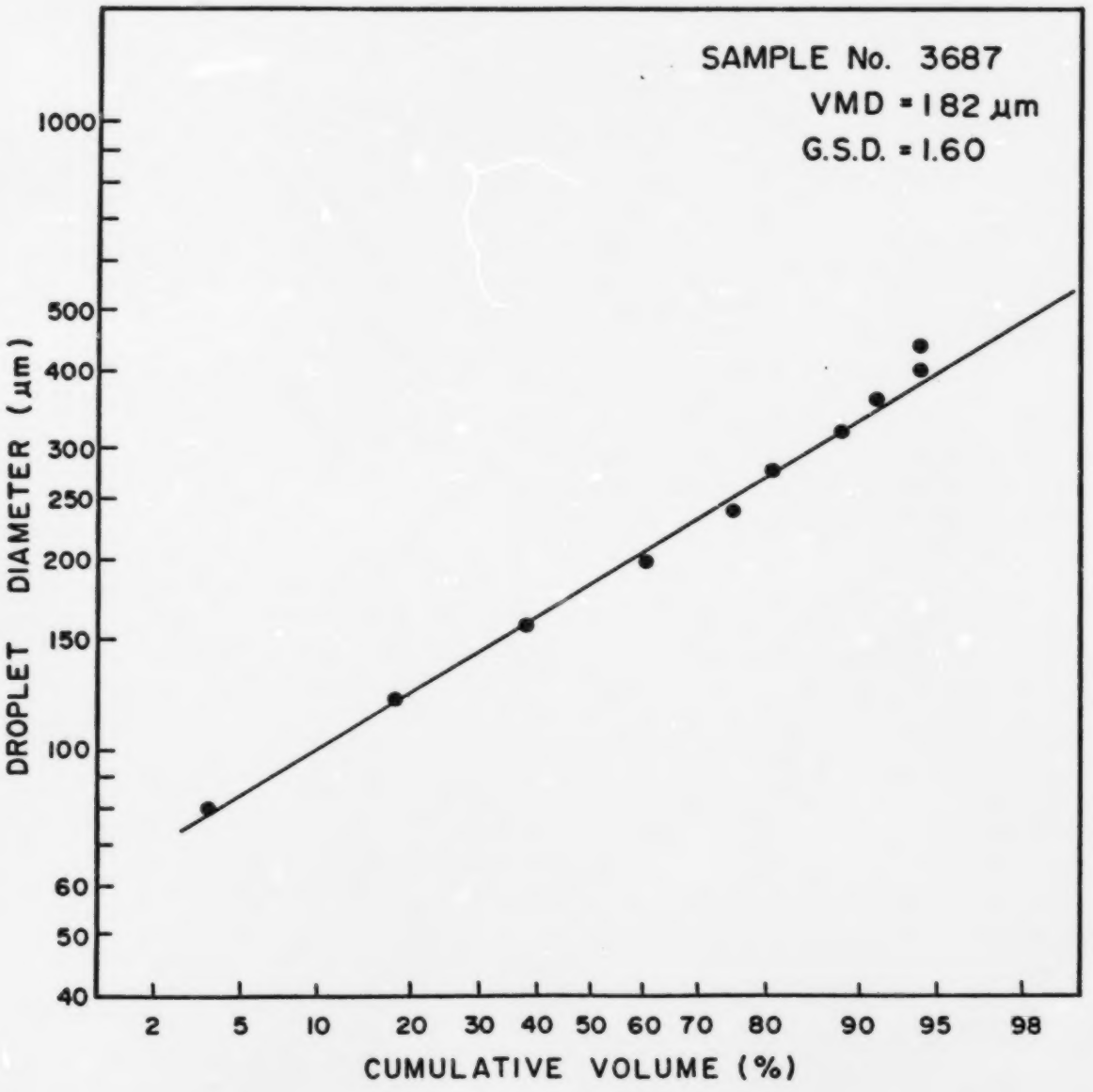

Figure 2. Droplet size distribution of spray deposited on the upwind side of swath ground.

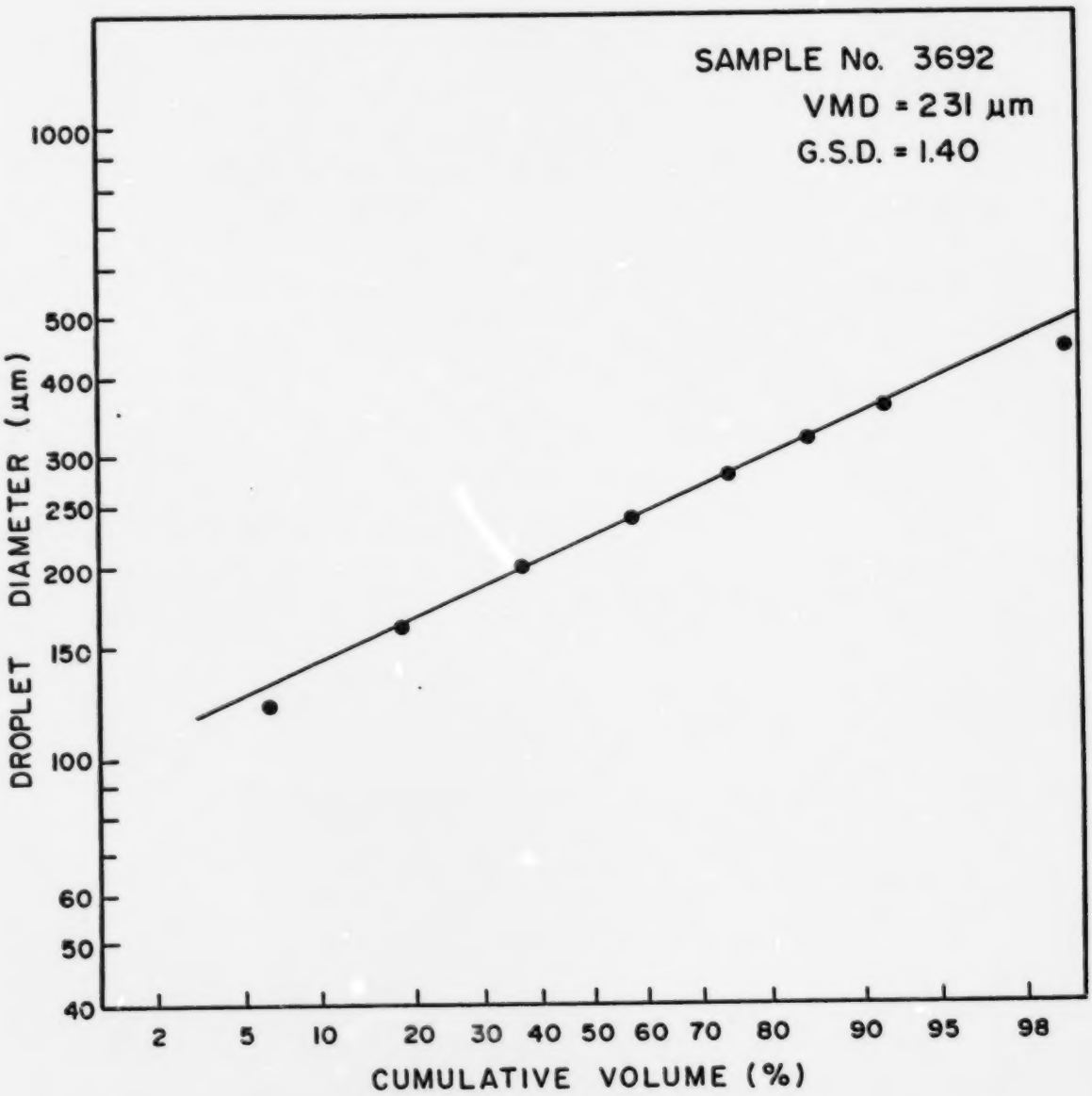

Figure 3. Droplet size distribution of spray deposited on the top of crop canopy in upwind side of swath.

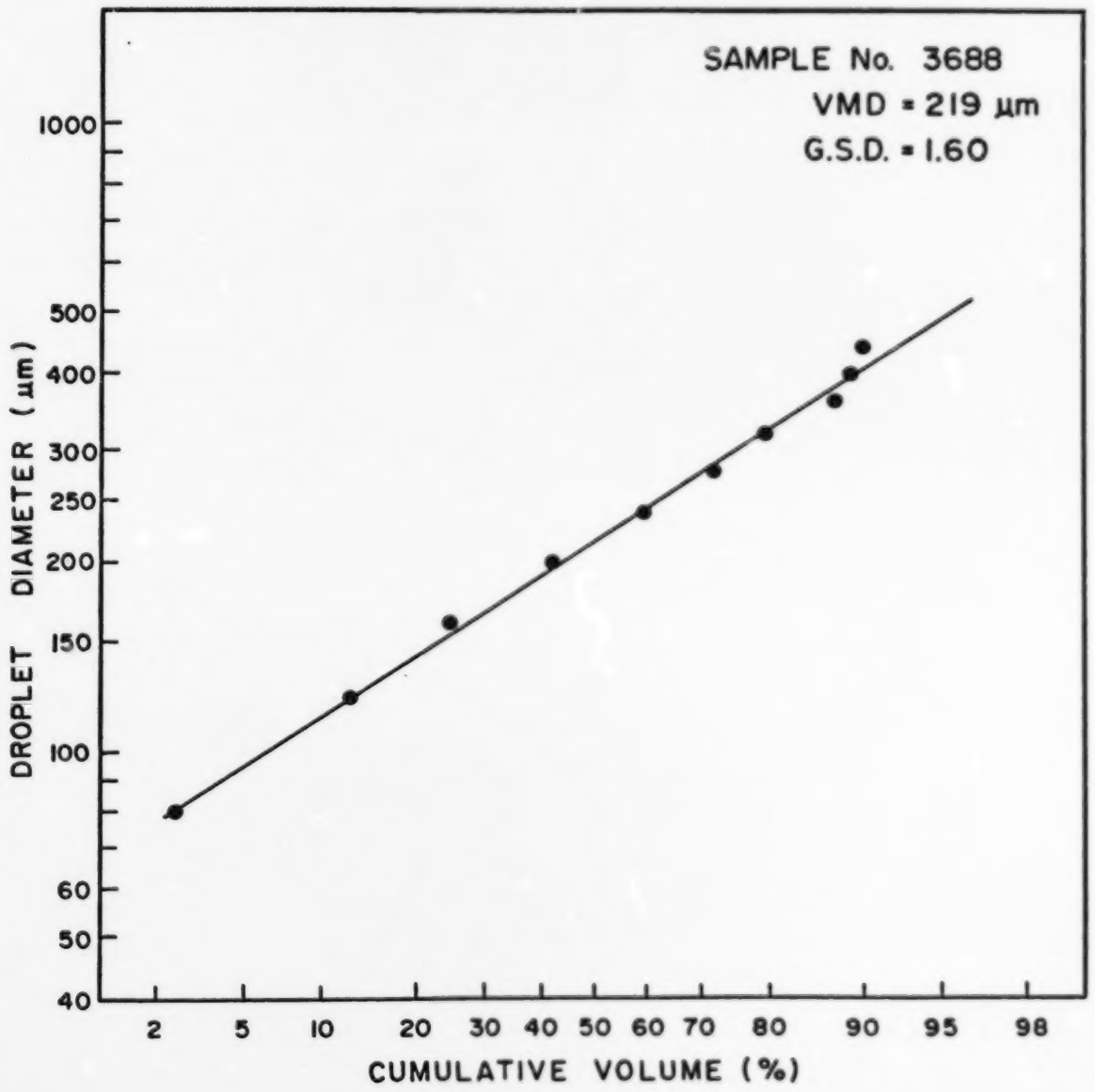

Figure 4. Droplet size distribution of spray deposited on the top of crop canopy in downwind side of swath.

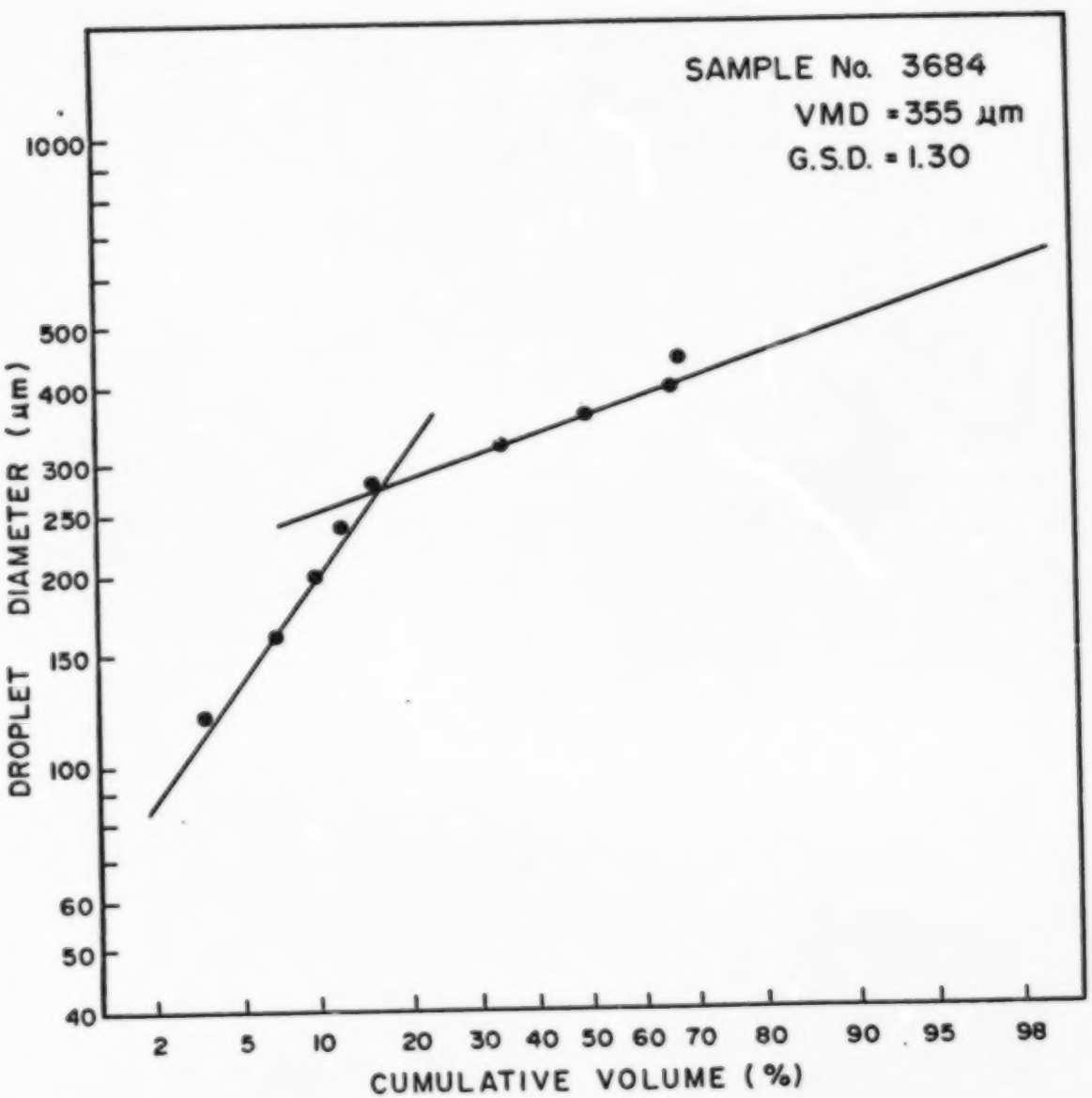

Figure 5. Droplet size distribution of spray deposited on the downwind side of swath ground.

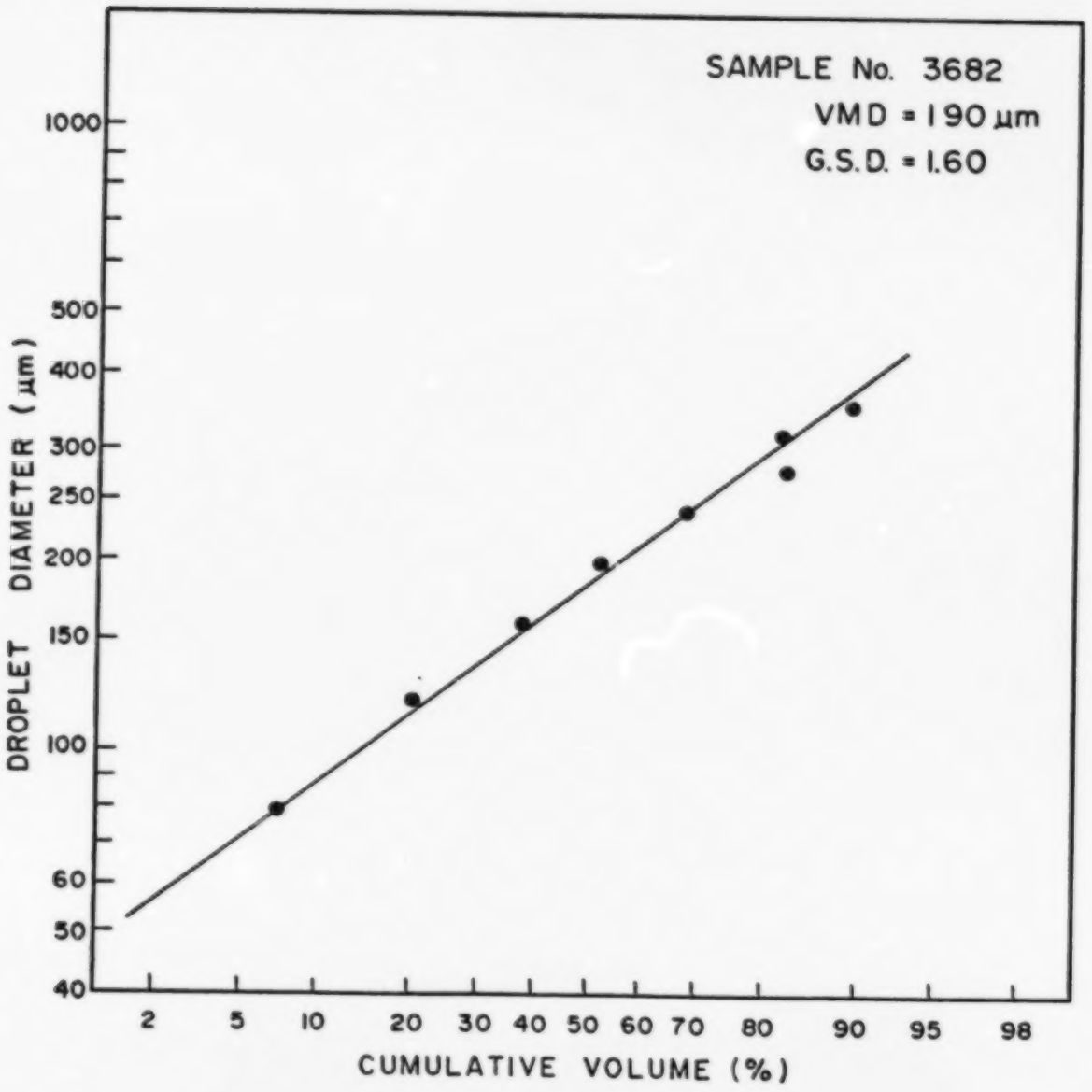

Figure 6. Droplet size distribution of drifting spray deposited at 5 m downwind ground.

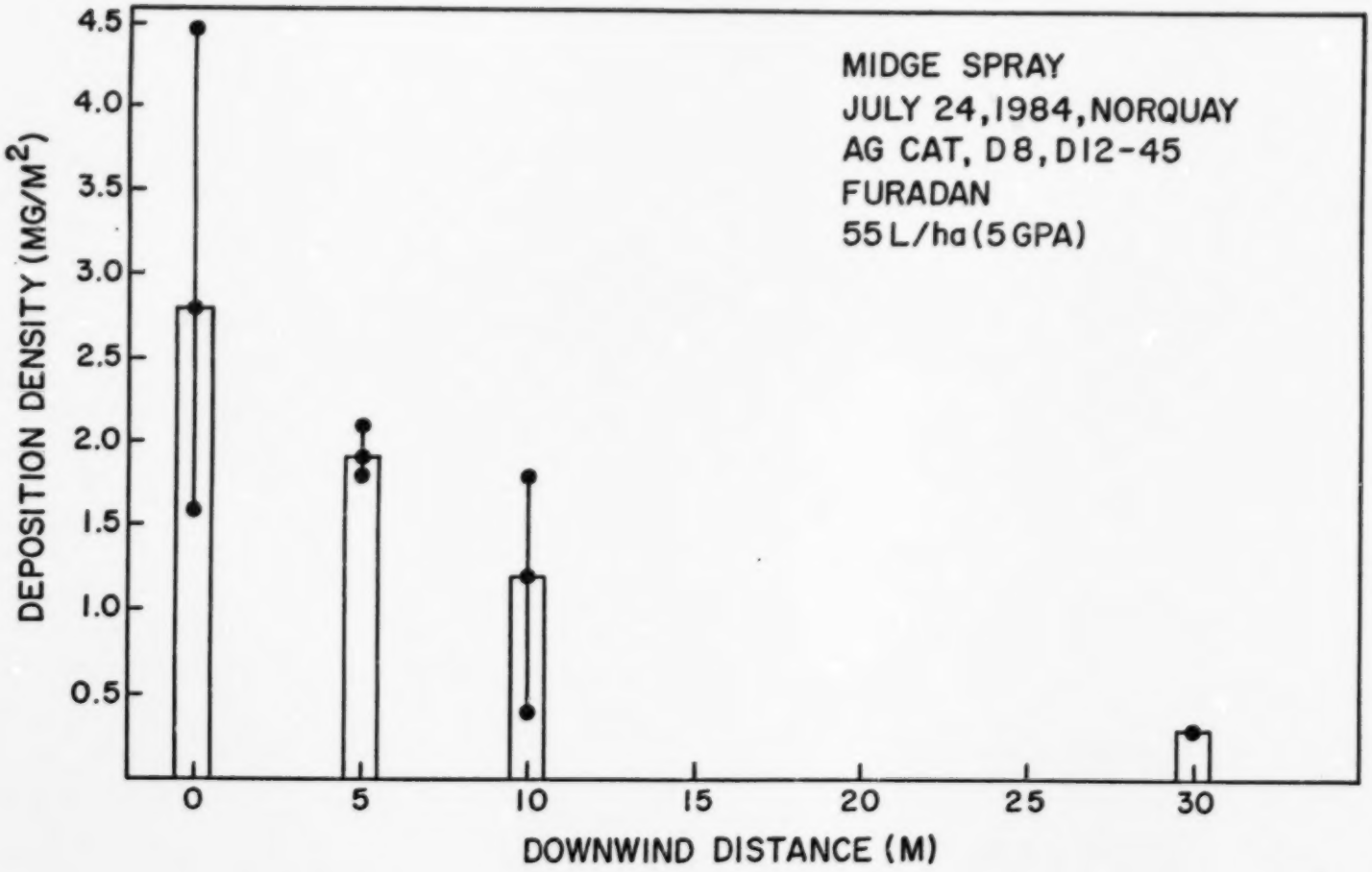

Figure 7. Distribution of downwind spray drift